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Objective: To investigate the relationship between chronic multisymptom illness (CMI) and possible exposure to an open-air burn pit at three selected bases among those deployed to operations in Iraq and Afghanistan. **Methods:** Chronic multisymptom illness (reporting at least one symptom in at least two of the following symptom constructs: general fatigue; mood and cognition problems; and musculoskeletal discomfort) was assessed, differentiating by potential burn pit exposure, among deployers who completed 2004 and 2007 Millennium Cohort questionnaires. **Results:** More than 21,000 Cohort participants were deployed in support of the current operations, including more than 3000 participants with at least one deployment within a 3-mile radius of a documented burn pit. After adjusting for covariates, no elevated risk of CMI was observed among those exposed. **Conclusions:** There was no increase in CMI symptom reporting in those deployed to three selected bases with documented burn pits compared with other deployers.

Though few objectively assessed health outcomes have been associated with 1991 Gulf War deployment,[1–4] as many as 15% of the nearly 700,000 returning 1991 Gulf War veterans have increased symptom reporting compared with their military peers.[5–13] Numerous research teams and expert panels were largely unsuccessful in clearly implicating any specific war exposure as a cause of postwar symptoms, which is noteworthy, given the large and continued military presence in the region. Many researchers believe this increase in symptom reporting among those deployed to the 1991 Gulf War may be associated with an exposure that could not be identified during that time.[5,9] Recently, much media and veteran concern has focused on possible health implications of exposure to smoke from open-air burn pits in theater.[14–16] The open-air burning of trash and other waste in theater is a practical solution for trash and waste disposal at bases of operations. However, the unknown nature of the chemicals released in this process has many veterans concerned that illnesses they have developed postdeployment may be because of burn pit smoke exposure. Recent analyses suggest that toxins such as dioxin, benzene, particulate matter, hexachlorobenzene, volatile organic compounds, carbon monoxide, ash, heavy metals (such as arsenic), formaldehyde, hydrogen cyanide, nitrogen dioxide, sulfur dioxide, and polycyclic aromatic hydrocarbons are being released in the smoke from the fires, and many are known carcinogens and may cause other chronic illnesses.[16–26] In fact, the Department of Veterans Affairs has recently acknowledged the possible health effects of burn pit exposure by providing benefits to veterans who self-report this type of exposure and have a variety of health conditions.[26]

The Millennium Cohort Study was designed to assess symptoms, illnesses, exposures, and behaviors (such as tobacco and alcohol use) among US military service members, including all Service branches, active-duty, Reserve, and National Guard members, over time, even after separation from the military. This study examined the reporting of chronic multisymptom illness (CMI) in relation to burn pit exposure in this cohort.

METHODS

The Millennium Cohort Study began collection of baseline data in July 2001, before the start of the military operations in Iraq and Afghanistan, and obtains follow-up data approximately every 3 years. Follow-up data for the first enrollment group were collected between June 2004 and February 2006 (n = 55,021), and again between May 2007 and December 2008 (n = 54,790).[27,28] A second enrollment group was added to the Cohort in 2004 (n = 31,110), with collection of follow-up data in 2007 (n = 17,152). The current study used data from the 2004–2006 and 2007–2008 survey cycles of the Millennium Cohort Study. Demographic and deployment-related data were obtained from the Defense Manpower Data Center (DMDC). This study was approved by the Institutional Review Board of the Naval Health Research Center, and the research was conducted in compliance with all applicable federal regulations governing the protection of human subjects in research (protocol NHRC.2000.0007).

Symptoms were assessed at both baseline (2004 to 2006) and follow-up (2007 to 2008) to identify CMI in participants who deployed in support of the operations in Iraq and Afghanistan. The

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case definition for CMI was based on the Centers for Disease Control and Prevention definition of an individual reporting at least one symptom in at least two of the following symptom constructs: general fatigue, mood and cognition problems, and musculoskeletal discomfort.[5,9] General fatigue was considered present when participants reported that they had "unusual fatigue." Mood and cognition was assessed through the presence of any of the following symptoms: "feeling down, depressed, or hopeless"; "problems with forgetfulness" or "difficulty concentrating"; "feeling irritable or having angry outbursts"; "feeling nervous, anxious, on edge, or worrying about a lot of different things"; "confusion"; and "trouble falling or staying asleep." The musculoskeletal construct had the following two symptoms: "pain in your arms, legs, or joints (eg, knees, hips)" and "unusual muscle pain."

Deployment dates for service members who were located within a 2-, 3-, or 5-mile radius of a documented open-air burn pit at three different camps in Iraq (Joint Base Balad [JBB], Camp Taji, and Camp Speicher) between 2003 and 2008 were provided by DMDC. Burn pit exposure was assessed using three different metrics. First, deployment status was dichotomized as either deployed near a documented open-air burn pit, or deployed to all other locations in support of the operations in Iraq and Afghanistan. Second, deployment was assessed by cumulative days exposed to a burn pit prior to baseline through the follow-up survey assessment and categorized into quartiles. Finally, exposure to one of the three camps with a documented burn pit, JBB, Taji, or Speicher, was also assessed. Participants who were deployed to multiple camps were categorized by the camp to which they were deployed for the longest period of time.

The primary analyses assessed the three burn pit exposures within a 3-mile radius. In subanalyses, all three burn pit exposures were also measured for a 5-mile radius. Deployment exposures for a 2-mile radius surrounding an open-air burn pit were restricted to Air Force personnel who deployed to JBB because of insufficient data for a 2-mile radius for the other two camps. The dichotomized burn pit exposure and cumulative days exposed to the open-air burn pit at JBB were assessed for a 2-mile radius.

Participants were excluded from the study if they did not complete the 2004 to 2006 or 2007 to 2008 questionnaires (n = 44,539), never deployed between 2003 and the 2007 to 2008 survey assessments (n = 33,207), or were missing CMI symptoms or any covariates (n = 1798). This study population was further restricted to Army and Air Force personnel because of the low number of Navy and Marine Corps personnel located within a 3-mile radius of the three documented open-air burn pits in this sample (n = 5490). After exclusions, there were 21,400 Millennium Cohort members included in this study population.

Multivariable logistic regression was performed for all analyses while adjusting for baseline covariates, including CMI status at baseline and burn pit exposure. Using a backwards statistical modeling strategy, variables that were not significant and not deemed to be confounders were manually removed to establish the final model. Sensitivity analyses were performed to test the possible effect of separation from the military on the association between CMI and burn pit exposure. Additional sensitivity analyses were conducted by extracting a subpopulation of Camp Arifjan deployers from the deployers who were not exposed to a documented burn pit because there are no documented open-air burn pits located in Camp Arifjan in Kuwait. Deployment to Arifjan was assumed if the length of deployment to Camp Arifjan was longer than the cumulative days deployed to all other locations in support of the operations, ensuring that the deployment was primarily to Camp Arifjan. Camp Arifjan deployment data were obtained from the DMDC. Finally, participants with CMI prior to follow-up were removed from the analyses to examine the possible effect of burn pit exposure on new-onset CMI. Statistical analyses were performed using SAS version 9.2 (SAS Institute, Inc, Cary, NC).

RESULTS

Of the 21,400 study participants, 3578 were identified with at least one deployment to an area within 3 miles of a documented burn pit. Those with burn pit exposure during deployment were more likely to be younger, less educated, in the Army, serving on active duty, and have occupation listed as "other" (ie, all other occupations excluding combat, health care, service, supply, and functional specialists) compared with those deployers who were not exposed (Table 1).

After adjusting for sex, birth year, education, service component, service branch, pay grade, smoking status, alcohol-related problems, mental health symptoms, and baseline CMI status, deployment within a 3-mile radius of a documented burn pit was not found to be significantly associated with CMI (P = 0.23) (Table 2). Although cumulative days deployed within 3 miles was not significant overall after adjusting for the variables listed earlier (P = 0.27), those exposed for more than 209 days had higher odds of CMI (Table 3). Proximity to a burn pit by camp (Table 3) was also not significantly associated with CMI after adjusting for the same variables described earlier (P = 0.36). Findings were consistent for the analyses using 5-mile radius burn pit exposures after adjusting for the same variables as the 3-mile radius analyses. There were 917 Air Force members identified as deployed within a 2-mile radius of the burn pit at JBB. Again, neither burn pit exposed, nor cumulative days exposed within a 2-mile radius of a burn pit, were significantly associated with CMI after adjusting for the variables listed in the 3-mile analyses (data not shown).

Other demographic, military, and behavioral covariates associated with CMI are shown in Table 2. After adjusting for symptoms of CMI at baseline, participants who had significantly higher odds of reporting CMI were women (adjusted odds ratio [AOR], 1.37, 95% confidence interval [95% CI], 1.27 to 1.49), born before 1960 (AOR, 1.43, 95% CI, 1.24 to 1.64), Army personnel (AOR, 2.50, 95% CI, 2.30 to 2.70), past and current smokers (AOR, 1.21, 95% CI, 1.12 to 1.32; AOR, 1.34, 95% CI, 1.22 to 1.47, respectively), and those who reported alcohol-related problems (AOR, 1.19, 95% CI, 1.06 to 1.33) and mental health symptoms (AOR, 2.32, 95% CI, 2.04 to 2.63). Participants who had significantly lower odds of reporting CMI had either a bachelor or an advanced degree (AOR, 0.69, 95% CI, 0.60 to 0.78; AOR, 0.74, 95% CI, 0.61 to 0.88, respectively), were Reserve/Guard members (AOR, 0.84, 95% CI, 0.78 to 0.90), and were officers (AOR, 0.69, 95% CI, 0.60 to 0.79).

Further examination revealed that 1869 (8.7%) study participants separated from military service by the 2007 to 2008 survey assessment. Models adjusted for separation status, in addition to aforementioned covariates, yielded similar nonsignificant findings for deployment within both the 2- and 3-mile radii and CMI (P = 0.06 and 0.08, respectively). However, CMI was significantly associated with deployment within a 5-mile radius after adjusting for the same variables (AOR, 1.10, 95% CI, 1.01 to 1.21). Models adding an adjustment for proximity to a burn pit by camp, including Arifjan, were not significantly associated with CMI when compared with those not exposed (P = 0.52). Furthermore, there were no increased odds of reporting CMI at JBB, Taji, or Speicher when compared with Arifjan after adjusting for the same variables listed earlier. There were 4580 study participants excluded for the new-onset CMI analyses. Of the 16,820 remaining participants, 2799 (16.6%) reported new-onset CMI at the 2007 to 2008 survey assessment. New-onset CMI was also not significantly associated with burn pit exposure at 2-, 3-, or 5-mile radii (P = 0.13, 0.64, and 0.54, respectively).

DISCUSSION

Growing concern over a broad range of potential exposures from smoke emanating from open-air burn pits in Iraq and Afghanistan has prompted the initiation of several studies to

TABLE 1. Baseline Characteristics of Millennium Cohort Deployers in Relation to Burn Pit Exposure Within 3-Miles (2003–2008)

Characteristic	Other Deployment* (*N* = 17,822)		Exposed Deployment† (*N* = 3,578)	
	n	%	*n*	%
Sex				
Male	13,505	75.8	2,651	74.1
Female	4,317	24.2	927	25.9
Birth year				
1980 and beyond	3,943	22.1	962	26.9
1970–1979	6,147	34.5	1,346	37.6
1960–1969	5,519	31.0	1,045	29.2
Pre-1960	2,213	12.4	225	6.3
Race/ethnicity				
White, non-Hispanic	12,590	70.6	2,410	67.4
Black, non-Hispanic	1,877	10.5	442	12.4
Other	3,355	18.8	726	20.3
Education				
High school or less	10,705	60.1	2,367	66.2
Some college	1,565	8.8	319	8.9
Bachelors degree	3,736	21.0	650	18.2
Advanced degree	1,816	10.2	242	6.8
Marital status				
Never married	6,137	34.4	1,333	37.3
Married	10,579	59.4	2,039	57.0
Previously married	1,106	6.2	206	5.8
Service branch				
Air Force	6,283	35.3	1,010	28.2
Army	11,539	64.7	2,568	71.8
Service component				
Active duty	8,740	49.0	1,960	54.8
Reserve/National Guard	9,082	51.0	1,618	45.2
Military pay grade				
Enlisted	13,069	73.3	2,718	76.0
Officer	4,753	26.7	860	24.0
Occupation				
Health care	1,480	8.3	365	10.2
Combat specialist	3,977	22.3	653	18.3
Functional support/service and supply	5,366	30.1	964	26.9
Other	6,999	39.3	1,596	44.6
Smoking status				
Nonsmoker	10,476	58.8	2,081	58.2
Past smoker	4,234	23.8	827	23.1
Current smoker	3,112	17.5	670	18.7
Alcohol-related problems‡				
No	16,131	90.5	3,247	90.7
Yes	1,691	9.5	331	9.3
Mental health symptoms‡§				
No	16,459	92.4	3,360	93.9
Yes	1,363	7.6	218	6.1
CMI at baseline				
No	14,540	81.6	3,013	84.2
Yes	3,282	18.4	565	15.8
CMI at follow-up				
No	13,214	74.1	2,622	73.3
Yes	4,608	25.9	956	26.7

Percents have been calculated for each column using the population size listed at the top of the respective columns. All characteristics were statistically significant ($P < 0.05$) in univariate analyses except smoking status, alcohol-related problems, and CMI at follow-up. CMI, chronic multisymptom illness; PHQ, patient health questionnaire.

*Deployment in support of the operations in Iraq and Afghanistan not within a 3-mile radius of a documented open-air burn pit.

†Deployment in support the operations in Iraq and Afghanistan within a 3-mile radius of a documented open-air burn pit.

‡Standardized PHQ scoring mechanisms were used to evaluate symptoms for alcohol-related problems, depression, and panic and other anxiety disorders.

§Participants who screened positive for depression, posttraumatic stress disorder, or panic or other anxiety disorders.

investigate health conditions potentially associated with this operational exposure. The extent of such an exposure and potential interaction with other military and geographic exposures is unknown. As a result, the authors conducted this exploratory analysis to address a continuum of acute and chronic symptoms that may be associated with exposure to burn pit smoke. In this population-based prospective study, CMI was evaluated and compared between personnel deployed to military camps with and without documented burn pits. After adjusting for many potential confounders, the authors found no increased risk of reporting CMI symptoms when comparing personnel within 2, 3, and 5 miles of a documented burn pit and when comparing length of time at the various camps. Overall, there was a small significant increase in risk among persons exposed for greater than 209 days. Though no conclusive findings were established between CMI and exposure to burn pits, the study highlights subgroups of the population with increased adjusted odds of CMI that should be investigated further.

In addition to prolonged exposure to burn pit smoke, several demographic, military, and behavioral variables were associated with symptoms of CMI in adjusted analyses. The fact that women and subjects with less education were more likely to report CMI was not surprising, given that these subgroups were more likely to report mental health symptoms at baseline, which may contribute to the fatigue or mood constructs of CMI.[29] One might expect older subjects to report more CMI because one of the main symptom constructs is musculoskeletal concerns, which would likely be higher in older subjects unless the symptoms were a result of injury. Findings that Army compared with Air Force, active duty compared with Reserve/Guard, and enlisted personnel compared with officers were more likely to report symptoms of CMI are shared with the reporting of depression symptoms in this population.[29,30] Because CMI and depression share several symptoms, such as feeling depressed, having trouble sleeping, feeling tired, and difficulty concentrating, it is not surprising that previous associations with depression in the Millennium Cohort are now seen with CMI. In addition, characteristics of being a past or current smoker, having alcohol-related problems, or mental health symptoms that were positively associated with CMI were also associated with reporting depression[29,30] and

TABLE 2. Adjusted Odds of CMI Among Deployers in Relation to Proximity to a Burn Pit, 2004–2008

	CMI						
Characteristic	***n****	**OR**	**95% CI**	***P***	**AOR†**	**95% CI**	***P***
Deployment within a 3-mile radius of a burn pit‡				0.2794			0.2307
No	4608	1.00	–		1.00	–	
Yes	956	1.17	0.96–1.13		1.06	0.96 – 1.16	
Sex				<0.0001			<0.0001
Male	3941	1.00	–		1.00	–	
Female	1623	1.39	1.30 – 1.49		1.37	1.27 – 1.49	
Birth year				<0.0001			<0.0001
1980 and beyond	1395	1.00	–		1.00	–	
1970–1979	1929	0.87	0.80 – 0.95		1.16	1.05 – 1.27	
1960–1969	1694	0.88	0.80 – 0.95		1.41	1.27 – 1.56	
Pre-1960	546	0.73	0.65 – 0.81		1.43	1.24 – 1.64	
Race/ethnicity				<0.0001			
White, non-Hispanic	3848	1.00	–				
Black, non-Hispanic	705	1.27	1.15 – 1.39				
Other	1011	0.95	0.88 – 1.03				
Education				<0.0001			<0.0001
High school or less	4000	1.00	–		1.00	–	
Some college	495	0.81	0.72 – 0.90		0.91	0.80 – 1.03	
Bachelors degree	740	0.46	0.42 – 0.50		0.69	0.60 – 0.78	
Advanced degree	329	0.43	0.38 – 0.49		0.74	0.61 – 0.88	
Marital status				0.0009			
Never married	1977	1.06	0.99 – 1.13				
Married	3195	1.00	–				
Previously married	392	1.26	1.11 – 1.42				
Service branch				<0.0001			<0.0001
Air Force	1060	1.00	–		1.00	–	
Army	4504	2.76	2.56 – 2.97		2.50	2.30 – 2.70	
Service component				<0.0001			<0.0001
Active duty	3161	1.00	–		1.00	–	
Reserve/National Guard	2403	0.69	0.65 – 0.74		0.84	0.78 – 0.90	
Military pay grade				<0.0001			<0.0001
Enlisted	4706	1.00	–		1.00	–	
Officer	858	0.42	0.39 – 0.46		0.69	0.60 – 0.79	
Occupation				<0.0001			
Health care	480	1.00	–				
Combat specialist	1100	0.89	0.78 – 1.00				
Functional support/service and supply	1798	1.13	1.00 – 1.27				
Other	2186	0.97	0.86 – 1.09				
Smoking status				<0.0001			<0.0001
Nonsmoker	2742	1.00	–		1.00	–	
Past smoker	1471	1.47	1.36 – 1.58		1.21	1.12 – 1.32	
Current smoker	1351	1.99	1.84 – 2.15		1.34	1.22 – 1.47	
Alcohol-related problems§				<0.0001			0.0035
No	4801	1.00	–		1.00	–	
Yes	763	1.84	1.67 – 2.03		1.19	1.06 – 1.33	
Mental health symptoms§, ¶				<0.0001			<0.0001
No	4531	1.00	–		1.00	–	
Yes	1033	6.36	5.70 – 7.09		2.32	2.04 – 2.63	
CMI at baseline				<0.0001			<0.0001
No	3144	1.00	–		1.00	–	
Yes	2420	7.77	7.20 – 8.38		5.27	4.85 – 5.73	

AOR, adjusted odds ratio; CI, confidence interval; CMI, chronic multisymptom illness; OR, unadjusted odds ratio.

*Number of participants with CMI during the 2007–2008 survey cycle.

†CMI model is adjusted for sex, birth year, education, service component, service branch, pay grade, smoking status, alcohol-related problems, mental health symptoms, and baseline CMI status. Other variables were removed from the final model because they were not significant at the $P < 0.05$ level and not confounding.

‡Deployment in support of Operations Iraqi and Enduring Freedom within a 3-mile radius of a burn pit.

§Standardized PHQ scoring mechanisms were used to evaluate symptoms for alcohol-related problems, depression, and panic and other anxiety disorders

¶Participants who screened positive for depression, posttraumatic stress disorder, or panic or other anxiety disorders.

TABLE 3. Adjusted Odds of CMI Among Deployers in Relation to Cumulative Days of Exposure and Camps Within 3 Miles of a Documented Burn Pit, 2004–2008

	CMI						
Models	***n****	**OR**	**95% CI**	***P***	**AOR†**	**95% CI**	***P***
Days deployed within 3 miles of a burn pit‡				0.0006			0.2727
0	4608	1.00	–		1.00	–	
1–56	246	1.06	0.92–1.24		0.97	0.82–1.14	
57–131	223	0.97	0.83–1.13		1.06	0.89–1.26	
132–209	205	0.86	0.73–1.00		1.01	0.85–1.21	
>209	282	1.33	1.15–1.53		1.19	1.02–1.40	
Camp with a documented burn pit§				<0.0001			0.3630
No burn pit exposure	4608	1.00	–		1.00	–	
JBB	520	0.90	0.82–1.00		1.08	0.96–1.22	
Speicher	240	1.19	1.02–1.39		0.96	0.81–1.14	
Taji	196	1.41	1.19–1.68		1.12	0.92–1.36	

AOR, adjusted odds ratio; CI, confidence interval; CMI, chronic multisymptom illness; JBB, Joint Base Balad; OR, unadjusted odds ratio.

*Number of participants with CMI during the 2007–2008 survey cycle.

†CMI models are adjusted for sex, birth year, education, service component, service branch, pay grade, smoking status, alcohol-related problems, mental health symptoms, and baseline CMI status.

‡Categories found by computing quartiles of days exposed to the burn pits among deployers exposed from 2003–2008.

§Deployment in support the operations in Iraq and Afghanistan within a 3-mile radius of a camp with a documented open-air burn pit. Participants who were deployed to multiple camps were categorized by the camp to which they were deployed for the longest period of time.

posttraumatic stress disorder (PTSD).[31] These similarities in symptom reporting for CMI and mental health disorders underscore the fact that it may be difficult to assess to what degree reported symptoms are due to underlying mental health conditions or a different process that manifests as CMI. Our findings of greater risk subgroups for CMI parallel those of previous CMI research conducted on 1991 Gulf War veterans.[5,32]

Chronic multisymptom illness occurs in military and nonmilitary populations and is associated with other conditions and functional status. Deployed US veterans of the first Gulf War with CMI were found to have a higher frequency of dyspepsia, hypertension, and metabolic syndrome compared with those deployed without CMI.[5] Australian Gulf War veterans with multisymptom illness had a higher frequency of depression, PTSD, chronic fatigue, functional impairment, and poorer quality of life.[32] The presence of CMI, therefore, may identify an individual with a higher number of comorbidities or at greater risk for adverse health outcomes.

A recent article in *Lancet Oncology* indicated, "Up to 227 metric tons of waste were burned daily (burn pits at Balad Air Base), reportedly including asbestos, solvents, unexploded ordinance, hydrogen cyanide, batteries, tires, plastics, feces, and medical wastes . . . " and reports of cancer and other chronic diseases have been attributed to toxic exposures from these burn pits.[33] The acute effects of smoke particles and gases from open-air burning include irritation of the eyes and respiratory tract among personnel with high exposures. Incomplete combustion of medical or latrine wastes could also potentially result in the emission of microbe-laden aerosols that may contribute to both acute and chronic illness.[21] There is also concern that exposure to dioxin might have been increased because of open burning of plastics (eg, water bottles) at less than the high temperatures reached during incineration needed to render these substances inert.[14] The ubiquitous nature and bioaccumulation of dioxins as an environmental contaminant add to total body burden related to usual occupational or environmental exposures such as stress, dust or sand storms, and extreme weather conditions. The potential for the development of cancer, birth defects, reproductive disorders, and immunotoxicity has been recognized, as well as the possibility of other adverse health outcomes, including liver disease, thyroid dysfunction, lipid disorders, neurotoxicity, cardiovascular disease, and metabolic disorders such as diabetes.[34] Although toxic substances are emitted as by-products of combustion from open-air burn pits, the risk to health is considered low following exposure to all analyzed substances with concentrations of analytes rapidly falling off with distance from the source or plume.[14] Furthermore, on the basis of information from the screening risk assessment about the airborne dioxin exposure levels of JBB in 2007, the Defense Health Board concluded that no dioxin-related short- or long-term health risks would be expected among personnel deployed to Balad.[15,35]

These data do not provide strong evidence for an association between burn pit exposure and subsequent short-term development of CMI. There was no overall association between exposure as assessed using the measures we employed on the basis of proximity and this outcome. A small subgroup with prolonged exposure (>209 days) did appear to have a statistically significant increase in risk of CMI (Table 3). This relationship held true even after adjustment for demographic, military, and behavioral characteristics. Prolonged breathing of smoke, especially among those with preexisting health conditions, may be associated with adverse health effects including unusual fatigue,[19] one of the main symptom constructs of CMI, highlighting the biologic plausibility of the association between lengthy exposure to burn pit smoke and reported symptoms of CMI. However, it should be noted that the measure of effect for this association was weak. Furthermore, there was no evidence of a trend for increasing risk of CMI with increasing exposure time, which weakens the argument for a potential causal relationship. A threshold effect is a possibility that should be examined in further research.

Analyses conducted on 2-, 3-, and 5-mile radii yielded no increase risk of reporting symptoms of CMI as participants' proximity to a burn pit increased. This is most likely because the increase in radius yielded few additional exposed subjects, due to the small difference in numbers of deployed personnel who were within a 5-mile radius who were not within a 3-mile radius of an open-air burn pit. Sensitivity analyses involving Camp Arifjan were conducted because it has no documented burn pit and has its waste transported out of the area for disposal. Furthermore, Camp Arifjan is located in the same geographical region with similar meteorological conditions as

the three camps with documented burn pits. There was no increase in CMI symptom reporting among those exposed to a burn pit when Arifjan deployers were the control group, which reinforces the primary findings of this study. Previous studies have found elevated levels of depression and PTSD among service members who have separated from the military.[36–39] To possibly explain the lack of a significant association between burn pit exposure and CMI, additional analyses were conducted that controlled for military separation. There was no indication that separation from the military was confounding CMI and burn pit exposure at the 2- and 3-mile radii, emphasizing the primary results. However, burn pit exposure at the 5-mile radius was marginally significant with CMI after controlling for military separation. New-onset CMI was examined to further investigate the potential causal relationship between burn pit exposure and CMI symptom reporting. No increased risk of new-onset CMI for those exposed to 2-, 3-, or 5-mile radii of a documented open-air burn pit was found, further strengthening the primary results.

There are several limitations to this study. The study population consists of a sample of Millennium Cohort participants and may not be representative of the military population in general. However, investigation of potential biases in the Millennium Cohort have found the Cohort to be representative, specifically with respect to health care use between responders and nonresponders prior to study initiation and reliable reporting of data by study participants.[28,29,40–48] The Centers for Disease Control and Prevention requires CMI symptoms to be present for at least 6 months. The Millennium Cohort questionnaires, however, assess these symptoms over a shorter time frame, which may overestimate CMI in this population, though misclassification would be expected to be nondifferential. Furthermore, similar CMI prevalence has been reported in other studies.[5] Discrepancies in CMI classification may also be because of the presence of other symptom-based conditions such as chronic fatigue syndrome, fibromyalgia, and irritable bowel syndrome because these often occur as comorbid conditions.[5,46] Using a standardized disease definition for CMI may have lessened this problem. The incidence of CMI at follow-up could not be definitively measured because of the format of the CMI symptom questions; therefore, the prevalence of CMI was studied as the primary outcome. In addition, burn pit data include whether a deployer was living or working within a 5-, 3-, or 2-mile radius of a documented burn pit and do not allow measures of varied exposure levels at each site so is thus an insensitive measure for true inhalation exposure. Data from documented burn pits at only three camps were used and were categorized according to the longest exposure recorded without the ability to assess burn pit exposure over the entire theater of operation. Furthermore, this study was not able to include important information about meteorological conditions, the direction of the smoke plume during burning operations, density of the plume, how much time a person spent outside versus inside a shelter with filters or air conditioning or both, whether the service member spent the majority of their time away from the camp, and the types of materials burned at the pit sites. For these and other reasons, exposure misclassification may bias these results in either direction on the basis of random or nonrandom misclassification of exposure. Also, these analyses do not take into account the many other exposures found in theater such as particulate matter exposure from dust, fuel exposures, and other specific occupational exposures. Finally, the multiple comparisons conducted in this study were not accounted for by adjusting the alpha level, and thus, any statistically significant effect may be due to chance alone.

Despite these limitations, this study has a number of important strengths. This is the first study to prospectively analyze the relationship between CMI and deployment-specific exposures in a large population-based military cohort. The Millennium Cohort consists of active-duty, Reserve, and National Guard members from all military services, though this study included only Army and Air Force personnel because of the number of individuals exposed. It also includes service members while in service and follows individuals even after separation from the military. Importantly, symptom complexes such as CMI may be better assessed through self-report than through medical encounter data, making the Millennium Cohort Study well positioned through serial surveys to address this issue that is of importance to military and veteran populations.

In conclusion, though strengthened by a large sample but limited by potential misclassification of exposure, these data suggest that deployers exposed to a documented burn pit were not at overall elevated risk of CMI. Moreover, there is no indication that a particular camp is more likely to be associated with increased reporting of CMI symptoms than another camp. These data offer the first prospective glimpse at the problem of possible burn pit smoke exposure associated with CMI at a population level. Though CMI spans a complex and diverse set of symptoms, these analyses did not attempt to study the continuum of health outcomes and symptoms that may be associated with exposures to burn pit smoke. Rather, this study focused on a set of symptoms reported to be associated with 1991 Gulf War deployment, and though reassuring at this early stage that there was no increase in CMI reporting differentiated by deployment to these large camps with burn pits, further follow-up is recommended. This study should not be considered an exhaustive investigation of this important health concern because there may be specific subgroups of deployed personnel with extensive exposure that may not have been identified in a population-based investigation such as this. Further research, including additional documented burn pit sites integrating meteorological data and other in-theater exposures, should be conducted for short- and long-term health outcomes potentially associated with open-air burn pit smoke exposure.

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14. ABSTRACT

Background
The open-air burning of trash and other waste in theater is a practical solution for trash and waste disposal at bases of operations. However, the unknown nature of the chemicals released in this process has many veterans concerned that illnesses they have developed post-deployment may be due to burn pit smoke exposure.

Methods
CMI (reporting at least two of the following symptom constructs: general fatigue; mood and cognition problems; and musculoskeletal discomfort) was assessed, differentiating by potential burn-pit exposure, among deployers who completed 2004 and 2007 Millennium Cohort questionnaires.

Results
Over 21,000 Cohort participants were deployed in support of the current operations, including >3,000 participants with at least one deployment within a 3-mile radius of a documented burn pit. After adjusting for covariates, no elevated risk of CMI was observed among those exposed.

Conclusions
There was no increase in CMI symptom reporting in those deployed to three selected bases with documented burn pits compared with other deployers.

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